The impacts of albedo, solar zenith angle and clouds on the transition from melt to freeze in the high-latitude Arctic.

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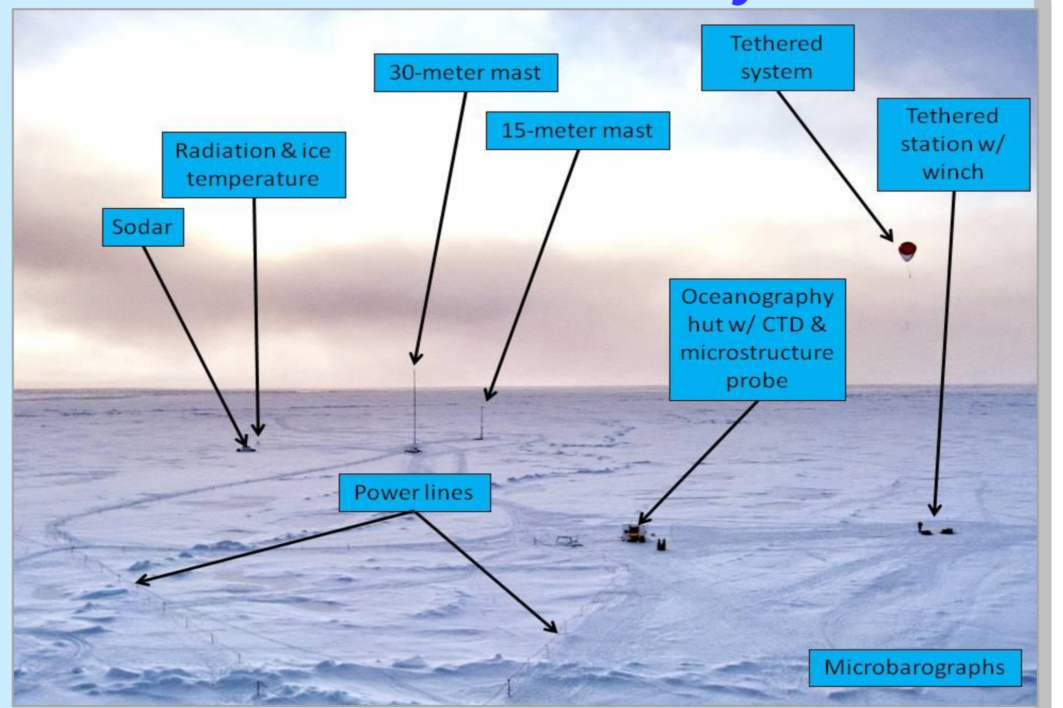
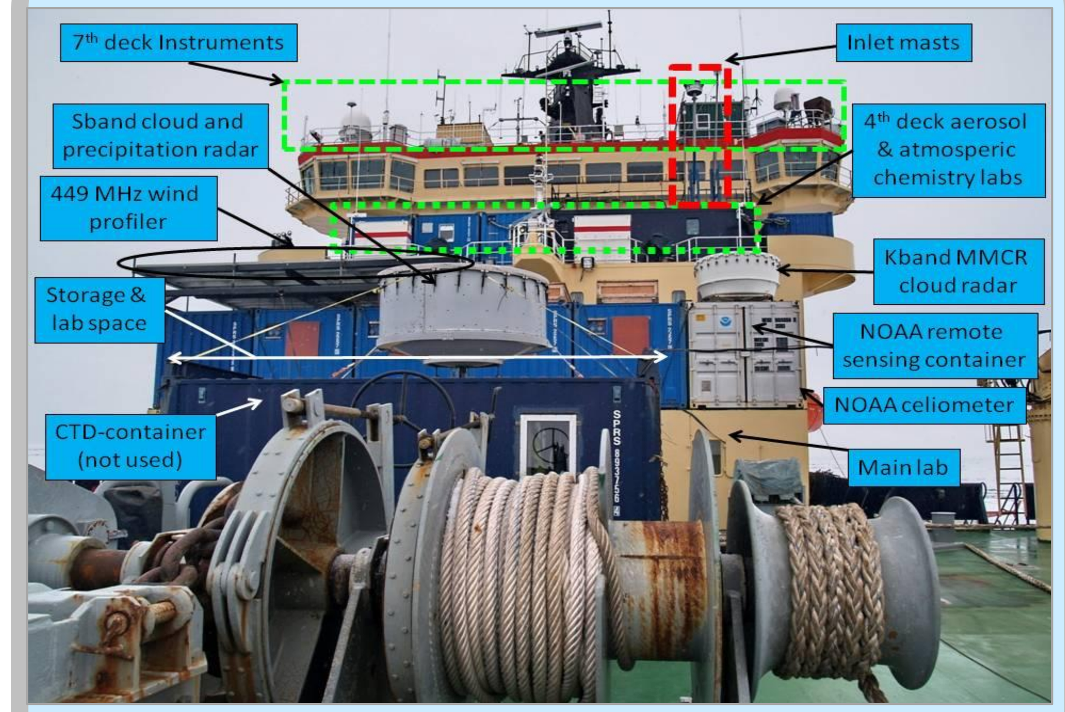
ASCOS

The "Met Alley"



The name "Met Alley" was adopted from an analogy with the SHEBA experiments "Met City". The observations are mostly related to atmospheric and oceanic energy fluxes, complemented with a SODAR and tethered soundings.

Oden's foredeck



The foredeck of Oden was dedicated to the surface-based remote sensing program. Cloud radars were deployed here along with several radiometers and a lidar celiometer. A weather station was located on the top deck.

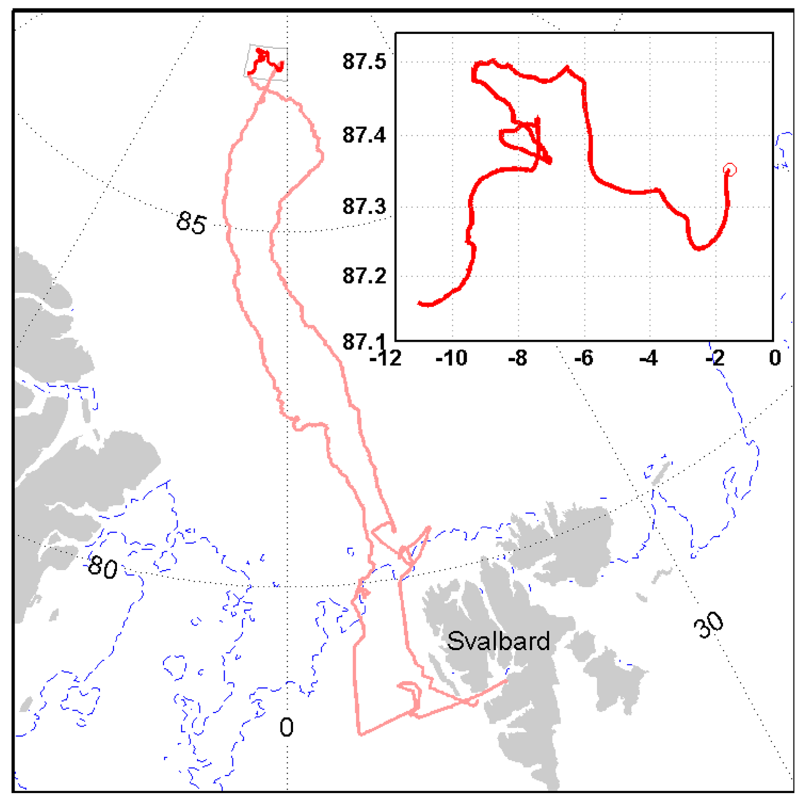
Where, when and how

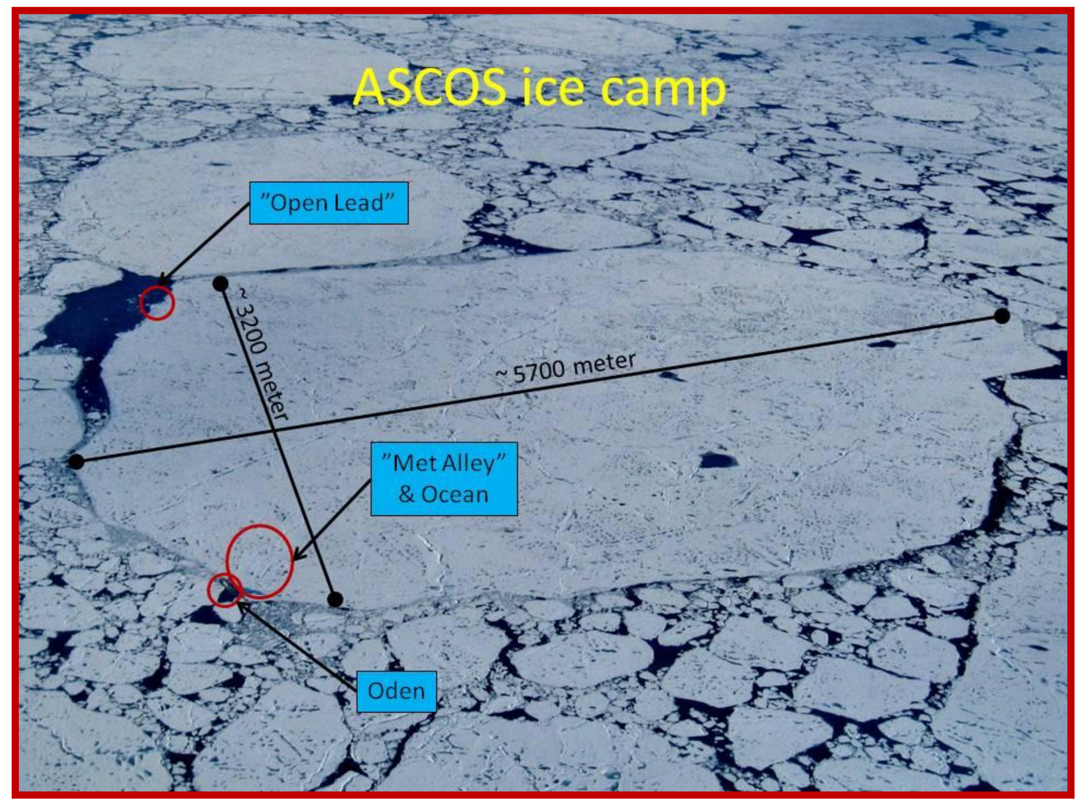
The Arctic Summer Cloud Ocean Study (ASCOS) was a 40-day research expedition, from 1 August to 9 September 2008, on the Swedish icebreaker *Oden*. The cruise track is shown below to the left. A main feature of ASCOS was a three-week ice drift, from 13 August to 2 September, 2008. During this period *Oden* was moored to a drifting 3 x 6 km large ice floe and served as a measurement platform, logistics base for work on the ice, and living quarters for the 33 scientists and 31 crew and logistics staff.

Measurements were carried out onboard the ship and on the near-by ice (see a subset in photos at the top), deploying both *in situ* instruments and surface-based remote sensing struments. On the ice two mast were instrumented to measure profiles of wind, temperature and turbulent fluxes, along with sensors for up- and downwelling short- and longwave surface radiation, heat conduction into the ice below the snow, and some other meteorological sensors.

Turbulent fluxes of heat from the ocean to the ice was also measured with instruments on an inverted mast under the ice. Spectral albedo and transmission of solar radiation through the ice was also measured.

Surface-based remote sensing of clouds and winds, and profiling of temperature, wind and humidity from soundings complemented the observations on the ice.

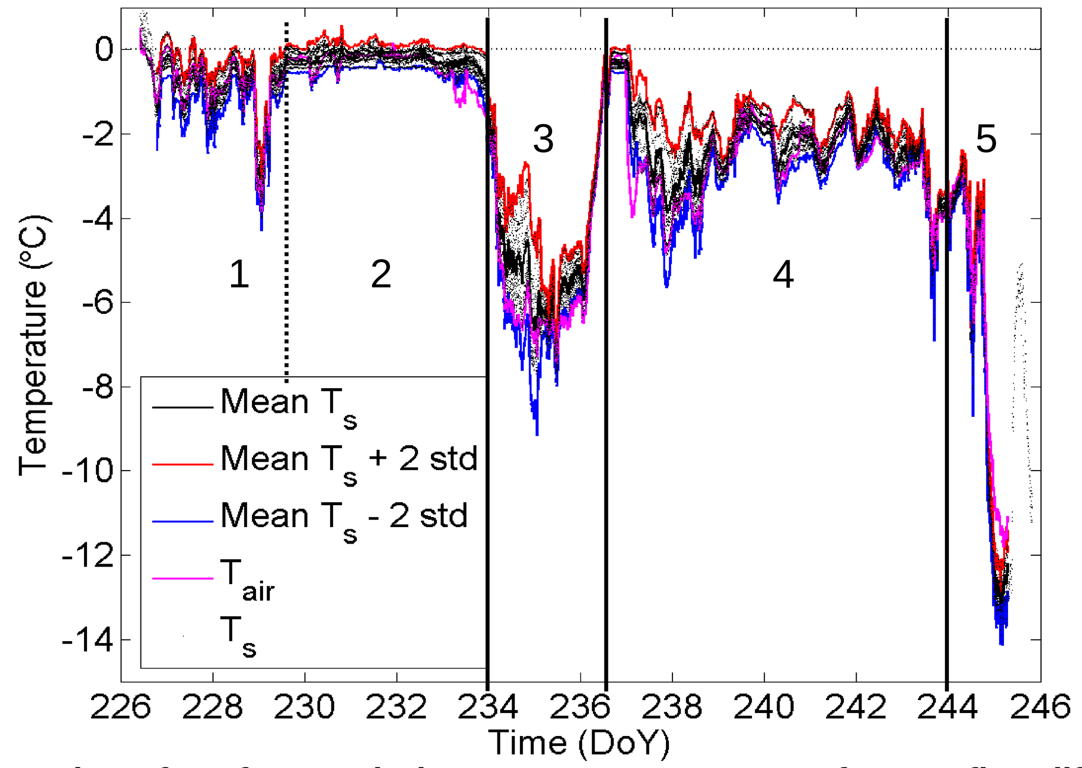




The objectives of this study

The transitions between summer-melt and autumn-freeze conditions are poorly understood, yet the length of the melt season, and consequently the settings for the following winter are partly set by this transition. Obviously, the summer melt is determined by the fact that solar radiation prevails, but is the transition simply determined by the gradual decline of the sun as autumn is approaching?

Within the scope of ASCOS (the Arctic Summer Cloud Ocean Study), one objective was to capture the fall transition between the late summer melt and the early autumn freeze-up. This was essentially successful. All all the components of the energy fluxes at and under the ice surface were measured during this transition, along with surface-based remote sensing of clouds and monitoring of the entire environment including atmospheric chemistry and aerosols . This allows a complete survey of the conditions that contributed to this transition



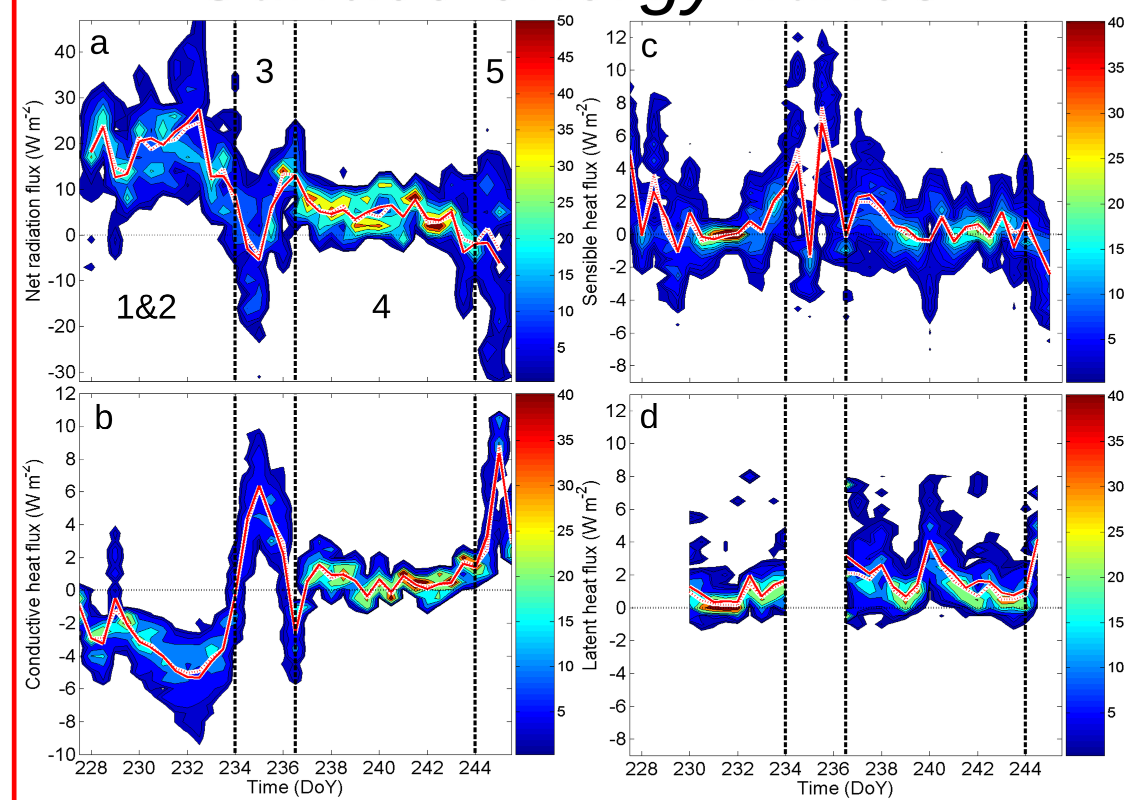
Time series of surface and air temperatures suggest four or five different regimes: #1&2 are part of the late summer melt, although different in variability; #3 is a brief cold period during which surface albedo changes; #4 is a transition period dominated by cloud forcing with temperatures near the freezing point of sea water and #5 is the actual start of the freeze-up.

Summary

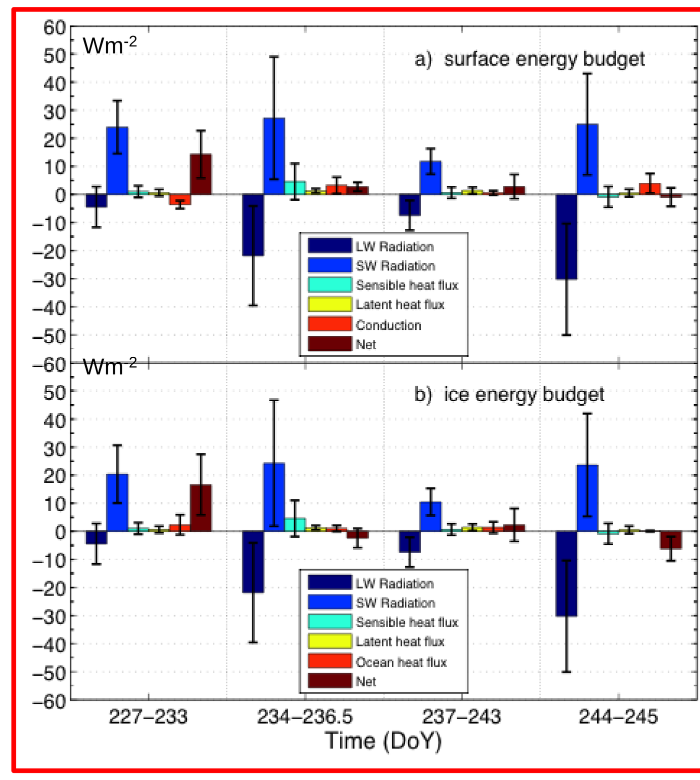
The surface temperature time series illustrates a series of regimes, where the first few days are at the end of the summer melt season. This regime is followed by a temporary cold period, mainly caused by advective processes; surface temperature is higher than near surface air temperature. Melt ponds and open water starts freezing and at the end a weather system with new snow passes. This permanently increases the surface albedo and although cloud radiative forcing is large and positive in the following period, surface temperatures never recover and as the clouds dissipate at the end, temperature plunges.

Results

Surface energy fluxes

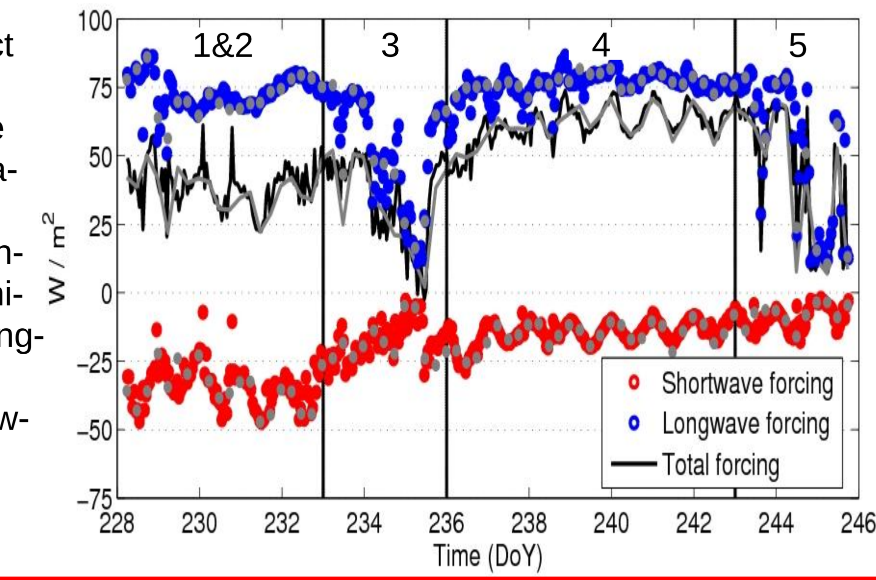


While it is hard to see the two first periods from the temperature trace, the surface energy flux measurements support the division into different regimes. Net radiation (a) dominates the energy budget and is over-all declining with time, but is clearly positive at the beginning, positive but small during period 4, and more negative in the colder periods. The turbulent surface heat fluxes are small and mostly positive (upward) throughout (c&d). The ice is being heated by the surface energy fluxes before during period 1&2 (b) but is losing heat the rest of the time, although only slowly during period #4.

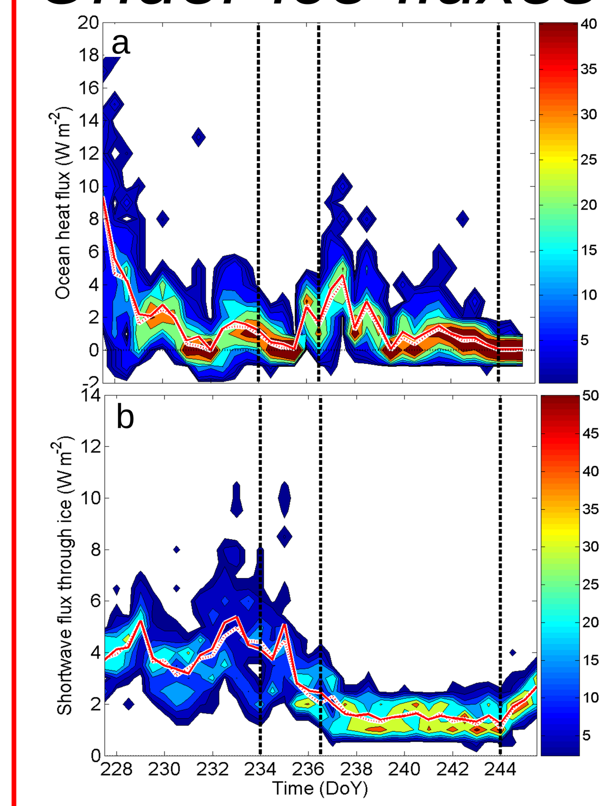


Adding the energy budget terms, for the snow surface (ignoring transmission of solar radiation through the ice and under-water sensible heat flux) and for the ice/snow layer as a whole (ignoring conduction), the first two periods have a clearly positive residual, indicating melting conditions. Periods 3&4 also has positive, but insignificant residuals, while the final period has a clearly negative residual; proper freezing has started.

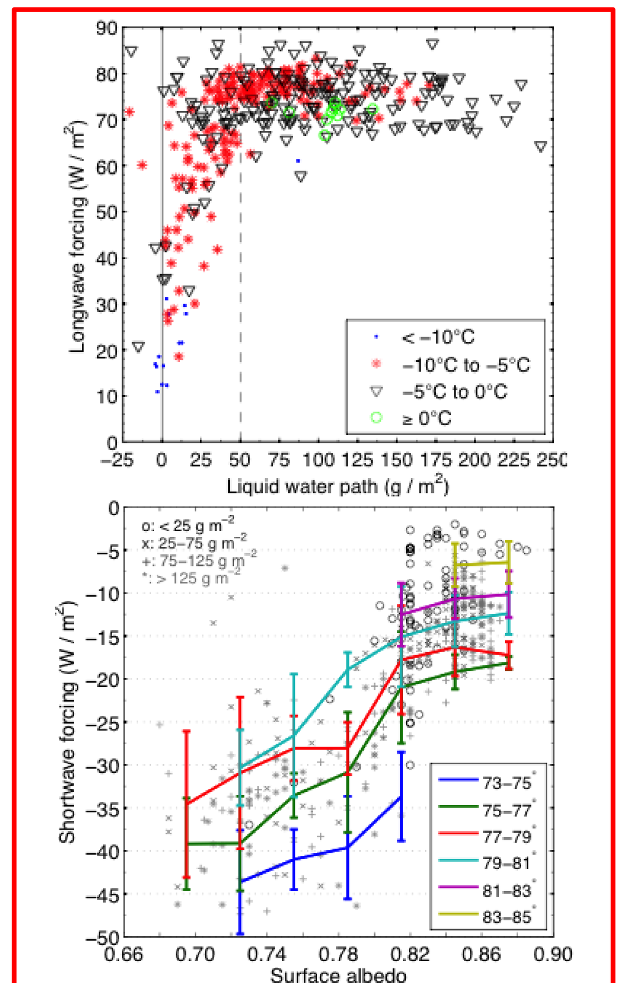
The cloud effect on the surface energy balance (the cloud radiative forcing) is positive throughout and is dominated by the longwave radiation, especially following the regime shift ending period 3.



Under-ice fluxes

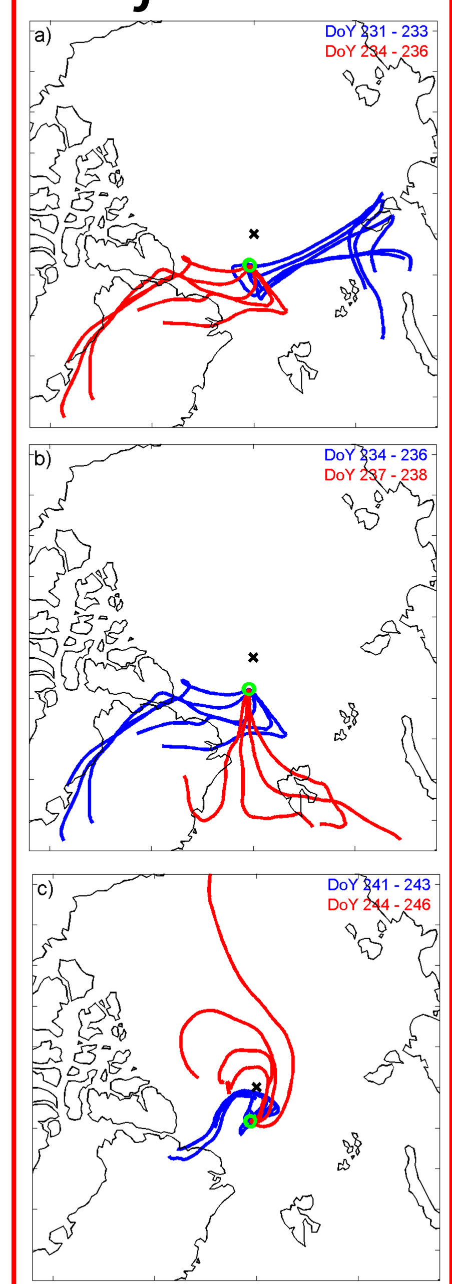


Sensible heat flux under the ice and solar radiation through the ice are small, but not negligble. The heat flux is larger during period 1. Shortwave radiation is relatively constant in periods 1&2 but displays an abrupt transition at the end of period 3; the passing of the weather system ending period 3. This snowfall, together with riming and freezing before it, permanently changed the surface albedo.



Longwave radiative cloud forcing is the stronger but depends mostly on cloud water content and saturates as the cloud becomes a "black body". The shortwave forcing, in contrast, is critically sensitive to surface albedo and solar zenith angle and is less sensitive to cloud water.

Trajectories



Changes in five-day back-trajectories for the full day before and after each transition (colors) indicate that these are primerely induced by changes in the larger scale meteorology.

Awcknowledgements

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